GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

PETROLEUM RESOURCE POTENTIAL OF OFFSHORE NEWFOUNDLAND AND LABRADOR

PETROLEUM DIRECTORATE

SPECIAL REPORT PD 83-1

ISSUED UNDER THE AUTHORITY
OF

THE HONOURABLE WILLIAM W. MARSHALL
PRESIDENT OF THE EXECUTIVE COUNCIL
AND
MINISTER RESPONSIBLE FOR THE PETROLEUM DIRECTORATE

AND

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EXECUTIVE DIRECTOR

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

PETROLEUM RESOURCE POTENTIAL OF OFFSHORE NEWFOUNDLAND AND LABRADOR

RESOURCE ASSESSMENT DIVISION

PETROLEUM DIRECTORATE

May, 1983

FOREWORD

Provisions of the Petroleum and Natural Gas Act, as amended, and the attendant Newfoundland and Labrador Petroleum Regulations, 1977, as amended, have resulted in all primary exploratory data gathered by the exploration companies being made available to the Petroleum Directorate.

Using this exploratory data, the Petroleum Directorate has made revised estimates of the potential hydrocarbon resource of Newfoundland's offshore areas.

This special publication was prepared by Martin Sheppard and David Hawkins of the Resource Assessment Division, Petroleum Directorate. R.G. Gosse reviewed the manuscript prior to its publication. Cindy Roche and Judy Ryall typed the report and Beth Decker and Ron Tucker drafted the figures.

Special Report PD 83-1 is issued under the authority of William W. Marshall, Minister Reponsible for the Petroleum Directorate and Steven M. Millan, Executive Director.

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SUMMARY AND CONCLUSIONS

Five hundred and seventy (570) individual geologic structures have been identified to date within the continental margin of Newfoundland and Labrador. Seven hundred and ninety three (793) potentially hydrocarbon-bearing horizons have been identified within the structures. The amount and type of hydrocarbon that an individual horizon might contain, was determined using reservoir engineering equations after having discounted for geologic risk and after analysis of relevant geochemical data.

A Monte Carlo statistical technique was employed to generate probability distributions for the amount of hydrocarbon in a horizon and that data was summated to produce distributions for the amount of hydrocarbon on a prospect basis, sector basis and total continental margin basis.

The major results of the evaluation are summarized as follows:

Total Continental Margin Resource Estimate

(A) Resource Potential for Crude Oil (Recoverable)

90 percent probability	2.4 billion barrels
50 percent probability	14.7 billion barrels
10 percent probability	86.3 billion barrels

(B) Resource Potential for Natural Gas (Recoverable)

90 percent probability	20.1 trillion cubic feet
50 percent probability	88.6 trillion cubic feet
10 percent probability	383.1 trillion cubic feet

INTRODUCTION

Terminology

For purposes of this report, 'resources' are defined as concentrations of naturally occurring liquid or gaseous hydrocarbons, some part of which is currently or potentially economically and technologicaliy extractable (modified after Dolton et al., 1981).

'Recoverable' as defined here, pertains only to that portion of the in-place resource that is extractable under primary and secondary methods of production.

Data Base

Evaluation of the petroleum resource potential of the Newfoundland continental margin has been an ongoing project within the Government of Newfoundland and Labrador since 1976. These evaluations have been and are being used by various government departments to assist in planning. For the purposes of this study, the continental margin of Newfoundland and Labrador has been divided into four sectors (i.e., Southern and Northern Grand Banks, Northeast Newfoundland Margin and Labrador Margin) as shown in Figure 1.

Petroleum exploration on the continental margin of Newfoundland and Labrador began in the early 1960's and by the end of 1982 some 270,000 line-miles of reflection seismic had

GJOA G-37
HEKJA O-71
CABOT G-91
RUT H-11
KARLSEFNI A-13
POTHURST P-19
GILBERT F-53
SKOLP E-7
OGMUND E-72
SNORRI J-90
HOPEDALE E-33
S LABRADOR N-79
CORTE REAL P-85
N BJARNI F-06
HERJOLF M-92
BJARNI H-81, O-82
TYRK P-100
GUDRID H-55
ROBERVAL K-92
ROBERVAL C-02
CARTIER D-70
N LEIF I-05
LEIF M 48, E-38
INDIAN HARBOR M-52
FREYDIS B-87
VERRAZANO L-77
HARE BAY E-21
BLUE H-28
BONAVISTA C-99
CUMBERLAND B-55
SHERIDAN J-87
LINNET E-63
WEST FLYING FOAM L-23
NAUTILUS C-92
BONANZA M-71
GABRIEL C-60
HIBERNIA
P-15 (oil)/susp
O-36(oil)/susp
J-34/susp
I-49/Drilling
TEMPEST G-88
NORTH DANA I-43
ADOLPHUS
BEN NEVIS I-45
HEBRON I-13
RANKIN M-36
ANGUILLE H-98
COOT K-56
HERMINE E-94
HERON H-73
J-72
TORS COVE W D-52
LABRADOR MARGIN
NORTHEAST NEWFOUNDLAND MARGIN
NORTHERN GRAND BANKS
SOUTHERN GRAND BANKS
NEWFOUNDLAND
QUEBEC
QUEBEC
NOVA SCOTIA
LEGEND
Well Location
Drilling Well
Suspended Well
Abandoned Well
Oil Well (abandoned)
Gas Well (abandoned)
Oil Producer
Gas Producer
Oil Well (suspended)
Gas Well (suspended)
70°
65°
60°
55°
50°
45°
40°
60°
55°
50°
45°

FIGURE 1

been collected (Figure 2) and operations had been carried out on 87 wells (Figure 3). Fifty-five wells had been operated on the Grand Banks, seven on the Northeast Newfoundland Margin and twenty-five on the Labrador Margin. This drilling effort has resulted in five significant gas-condensate discoveries on the Labrador Margin and five significant oil and gas discoveries on the Grand Banks. Most of the drilling to date has taken place on the continental shelf leaving the deeper water areas of the continental slope (two wells) and rise (no wells) virtually untested.

This report supersedes Petroleum Directorate Special Report PD 80-2 (Resource Assessment Division, 1980). Significant new drilling and seismic data have been acquired since that 1980 report was written. Methodology of assessment has not been significantly altered since the 1980 report but the scope of this new report (i.e., number of structures analysed) is much greater. The overall conclusions contained herein are much more sensitive to increase in useable data than they are to methodology. Furthermore, overall improvements have been made in the quality of geophysical data and improvements have also been made in the software used by the Petroleum Directorate in the evaluation of oil and gas resource potential. These factors have all contributed to the generation of this new Special Report PD 83-1.

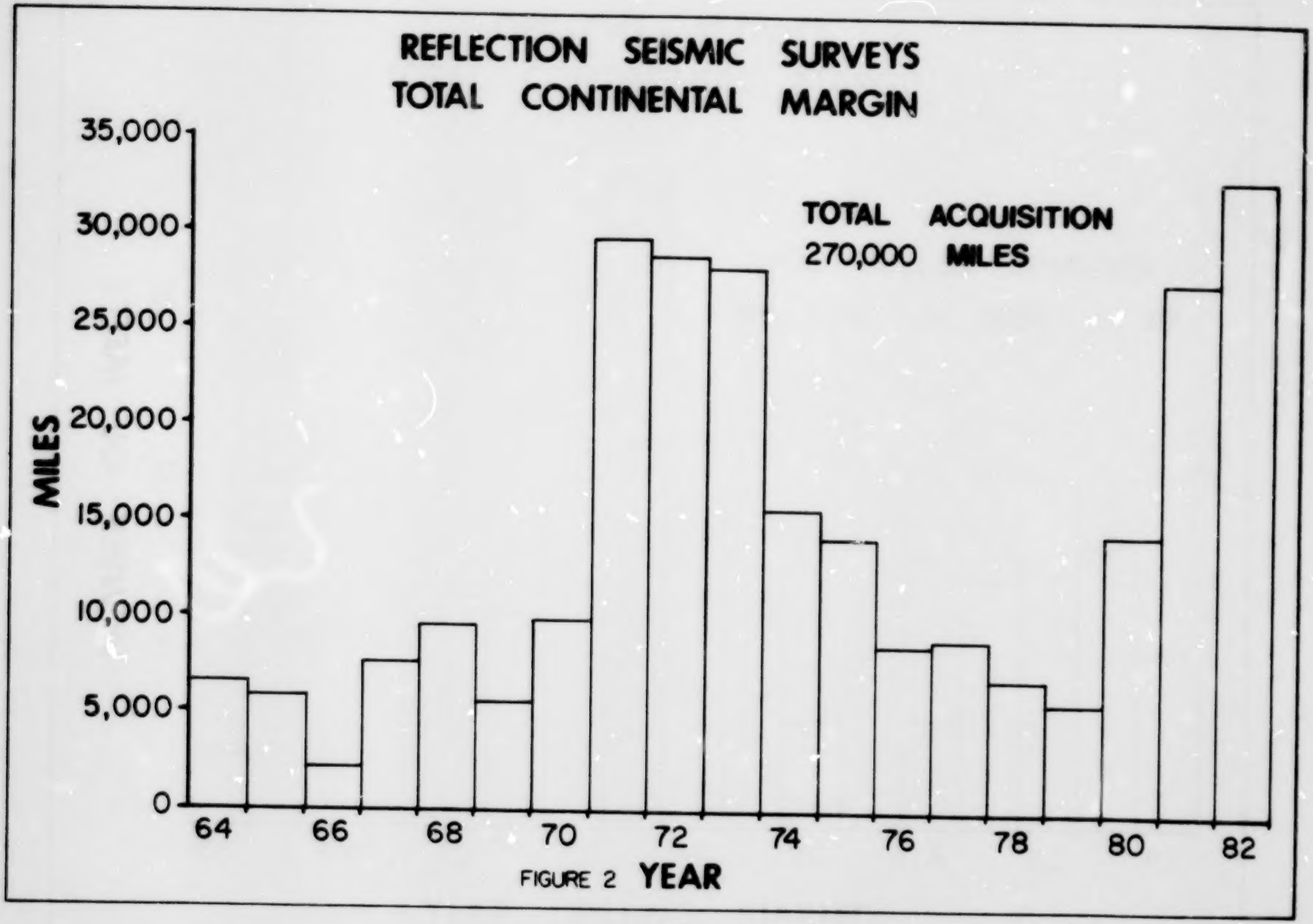

REFLECTION SEISMIC SURVEYS
TOTAL CONTINENTAL MARGIN
TOTAL ACQUISITION
270,000 MILES
MILES
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
64
66
68
70
72
74
76
78
80
82
YEAR

FIGURE 2

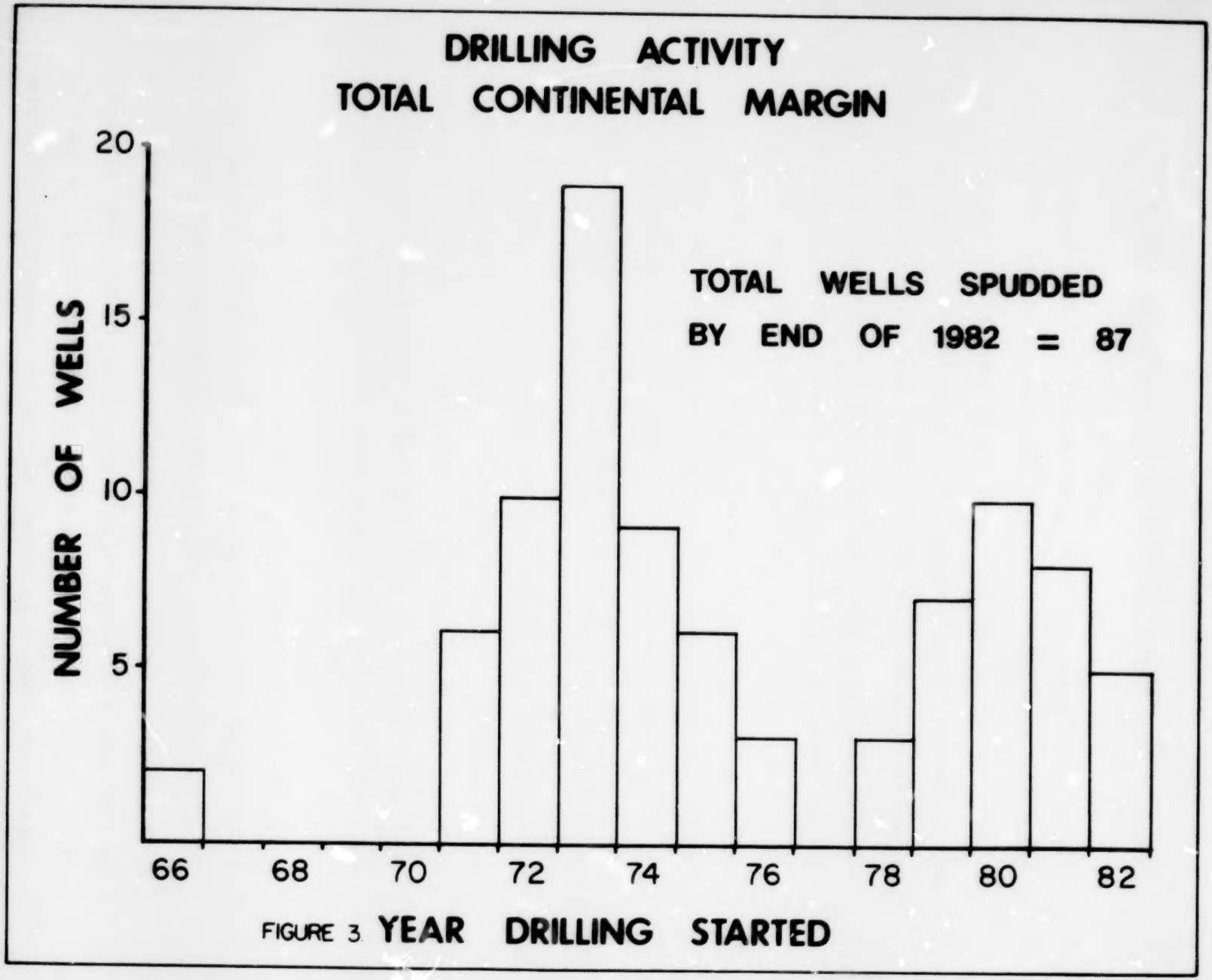

DRILLING ACTIVITY
TOTAL CONTINENTAL MARGIN
NUMBER OF WELLS
20
15
10
5
TOTAL WELLS SPUDDED
BY END OF 1982 = 87
66
68
70
72
74
76
78
80
82
YEAR DRILLING STARTED

FIGURE 3

METHODOLOGY OF PETROLEUM RESOURCE EVALUATIONS

The objectives in making estimates of resource potential are: (1) to determine the volume of oil and gas that may exist (2) to state the degree of certainty of the estimates (3) to determine where the resources are located (4) to determine how many structures have the potential for commercial development. This report attempts to determine the quantity of oil and gas that probably exists along the Newfoundland continental margin and as well to define the certainty of these evaluations. The areas within the continental margin where these resources appear to be concentrated are indicated but the fourth objective pertaining to commerciality is not addressed.

The resource assessment method can be broken into six stages as illustrated in Figure 4.

The first step involves documentation of all structures that are known to exist. The identification of structures was arrived at from interpretation of raw geophysical data and from numerous geological and geophysical reports which have been submitted by operators in accordance with the 1977 Petroleum Regulations.

The second step involves the identification of all horizons that may be potentially oil or gas-bearing within each structure. In step three, the chance of a horizon containing oil, gas or both is subjectively evaluated largely from available geochemical data. Reservoir parameters are defined in step 4. Where applicable, such parameters include closure, reservoir thickness, effective porosity, net pay, water

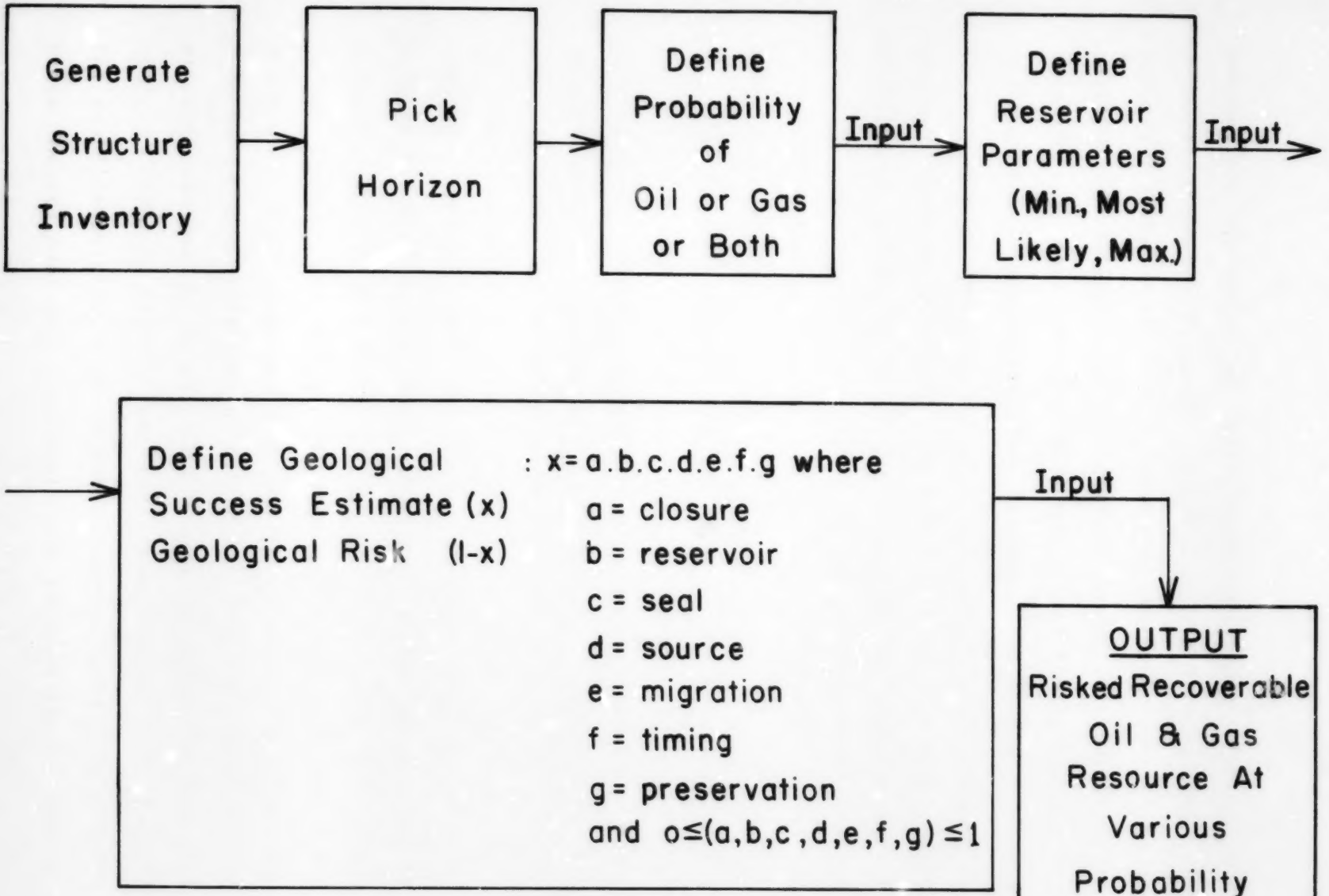


Fig. 4 Resource Assessment Method Utilizing Monte Carlo Resource Simulation Program.

saturation, percent trap fill, formation volume factor, oil recovery factor, reservoir temperature and pressure, gas compressibility, surface loss, and gas recovery factor. These various hydrocarbon volume factors were determined from existing well data and from regional correlations developed by staff of the Resource Assessment Division. In many cases these factors were assigned by subjective judgement from geologists, geophysicists and geochemists to supplement or fill gaps in the existing data base. Most of the parameters were assigned as a constant within particular basins or geographical locations but they were varied as much as possible on a horizon or individual structure basis.

Step 5 involves assigning geological risk by analyzing the geological elements which control the presence or absence of hydrocarbons. These elements include closure, reservoir, seal, source, migration, timing and preservation. Each horizon for every structure was risked individually.

Data collected in steps 1 to 5 is input and ran in a computer program that calculates resource potential. This program is based on a prospect assessment method as outlined by White et al. 1975 and White and Gehman, 1979, where hydrocarbon volume factors are multiplied together using a Monte Carlo procedure. Each hydrocarbon volume factor is entered into the program in the form of a triangular distribution, with a minimum, maximum and most likely value (Megill, 1977). This range in values reflects the uncertainty about each factor. The Monte Carlo simulation computer program is used to combine these factors over and over again (up to 3000 times) into an

overall probability representation of the recoverable resource. These values are then reduced by the geological risk factor (Step 5, above) and the resulting estimates represent the risked recoverable resource assessment for the particular horizon under consideration. The horizon estimates were summated to give structure, sector and continental margin totals. The number of structures evaluated is thought to be representative of the entire margin and adequate for purposes of estimation of the total resource.

ESTIMATES OF OIL AND GAS RESOURCES - TOTAL MARGIN

The continental margin of Newfoundland and Labrador covers an area of approximately 714,000 square miles. Within this area, a total of 793 potentially hydrocarbon-bearing horizons were identified within 570 individual structures. The trapping mechanisms for these structures belong to various play types including diapirs, rollover anticlines, block faults, drape over basement highs as well as stratigraphic pinchouts and units subcropping against erosional surfaces.

The resource estimates for potentially recoverable oil and gas are shown in Table 1. At the 50 percent probability level there are 14.7 billion barrels of recoverable oil and 88.6 trillion cubic feet of recoverable gas. These results do not include estimates for solution gas or natural gas liquids.

Figures 5 and 6 indicate by sector, the amounts of recoverable oil and recoverable gas respectively, at the probability level of 50 percent.

Table 1

Total Continental Margin
Resource Estimate

Probability (Percent)	Recoverable Oil Resource BSTB	Recoverable Gas TSCF
90	2.4	20.1
50	14.7	88.6
10	86.3	383.1

SOUTHERN GRAND BANKS

The Southern Grand Banks was the focus of activity during the early phase of exploration but results were very disappointing. Several major subbasins: the South Whale, Whale, Horseshoe, and Carson have been defined from reflection seismic surveys and through drilling. Many of these subbasins have been intruded by salt to various levels and many of the structures tested are in some way related to this salt movement.

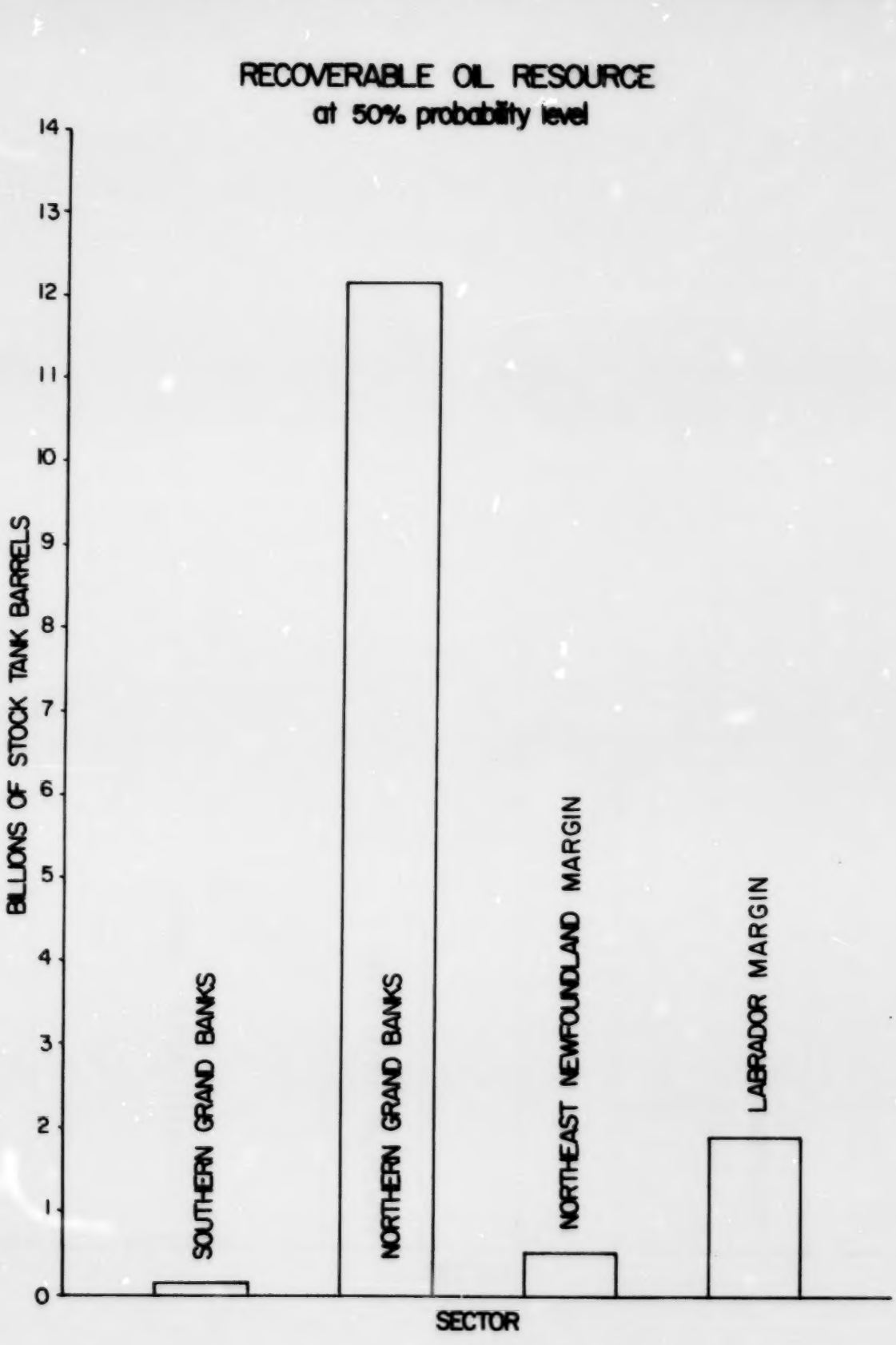

RECOVERABLE OIL RESOURCE
at 50% probability level
BILLIONS OF STOCK TANK BARRELS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
SOUTHERN GRAND BANKS
NORTHERN GRAND BANKS
NORTHEAST NEWFOUNDLAND MARGIN
LABRADOR MARGIN
SECTOR

FIG. 5

RECOVERABLE GAS RESOURCE
at 50% probability level

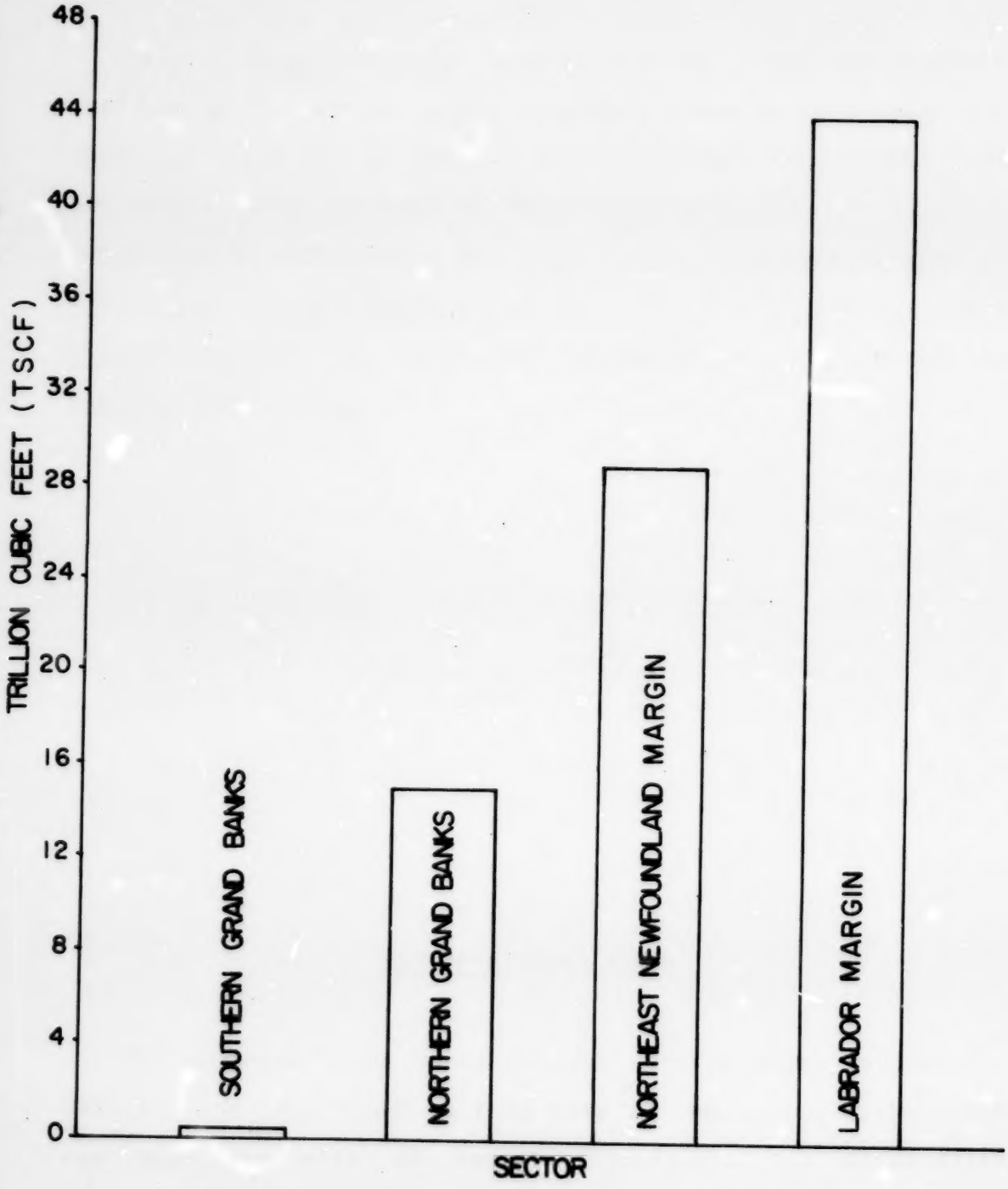


FIG. 6

Resource Estimates

Seventy-five structures were identified within the Southern Grand Banks sector and their summated resource potentials are shown in Table 2. At the 50 percent probability level there are 0.1 billion barrels of recoverable oil and 0.4 trillion cubic feet of recoverable gas. It should be emphasized that in comparison to other sectors the data available to the Petroleum Directorate for this particular evaluation is limited both in quantity and quality.

Table 2

Resource Potential for the Southern Grand Banks

Probability (Percent)	Recoverable Oil Resource BSTB	Recoverable Gas TSCF
90	0.01	0.1
50	0.1	0.4
10	0.8	1.7

NORTHERN GRAND BANKS

The Northern Grand Banks contain several major sedimentary basins. The best known at this time is the Avalon Basin which has been the site of recent significant oil discoveries (Hibernia, Hebron, Ben Nevis, and Nautilus). Furthermore,

noncommercial amounts of oil were discovered in 1973 at the Adolphus structure. The basin contains a thick Mesozoic and Cenozoic section with the Mesozoic section intruded at various levels by salt. The basin is bounded to the west by a major hinge fault, to the east by the Outer Ridge Complex, (where an additional oil discovery has been made at the South Tempest structure) and is separated from the Jeanne D'Arc subbasin to the south by a major normal fault.

The Jeanne D'Arc subbasin contrasts the Avalon Basin in that the thickness of the Cretaceous section in the former is considerably reduced.

The Flemish Basin, further to the east, also contains a thick Mesozoic and Cenozoic section but to date only one well (Gabriel C-60) has tested this section.

Resource Estimates

One hundred and thirty-four structures have been documented within the Northern Grand Banks and Table 3 lists the summated resource potential for the sector. At the 50 percent probability level there are 12.3 billion barrels of recoverable oil and 15.1 trillion cubic feet of recoverable gas.

Table 3

Resource Potential for the Northern Grand Banks

Probability (Percent)	Recoverable Oil Resource BSTB	Recoverable Gas TSCF
90	2.0	2.9
50	12.3	15.1
10	74.7	95.0

NORTHEAST NEWFOUNDLAND MARGIN

The Northeast Newfoundland Margin is dominated by the East Newfoundland Basin which contains an indicated maximum sedimentary thickness in excess of 45,000 feet. Only seven wells have been drilled in this sector and all were dry and abandoned. This area of the continental margin is one of the least known and explored. However, the area west of the East Newfoundland Basin may be an active exploratory area in the future as the industry looks for Hibernia type plays along the major hinge fault bordering the Bonavista Platform.

Resource Estimates

One hundred and fifty-five structures have been documented within the Northeast Newfoundland Margin sector and their summated resource potentials are shown in Table 4. At the 50 percent probability level there are 0.5 billion barrels of recoverable oil and 29.0 trillion cubic feet of recoverable gas.

Table 4

Resource Potential for the Northeast Newfoundland Margin

Probability (Percent)	Recoverable Oil Resource BSTB	Recoverable Gas TSCF
90	0.1	6.5
50	0.5	29.0
10	2.2	119.4

LABRADOR MARGIN

Twenty-five wells have been drilled on the Labrador Margin. Five significant gas-condensate discoveries have been made (Bjarni, Hopedale, Snorri, Gudrid, and North Bjarni). Reservoirs have been documented within the Paleozoic, Cretaceous, and Tertiary sections and the predominance of tested gas plus the results of source rock analyses have led many to define this area as a gas-prone province. However, discovery of oil in a recent well (Petro-Canada et al. North Leif I-05) indicates that this area should not be overlooked as a possible oil province. As well, areas located under deeper water towards the shelf edge remain virtually untested.

Resource Estimates

Two hundred and six structures have been documented within the Labrador Margin and their summated resource potentials are shown in Table 5. At the 50 percent probability level there are 1.8 billion barrels of recoverable oil and 44.1 trillion cubic feet of recoverable gas.

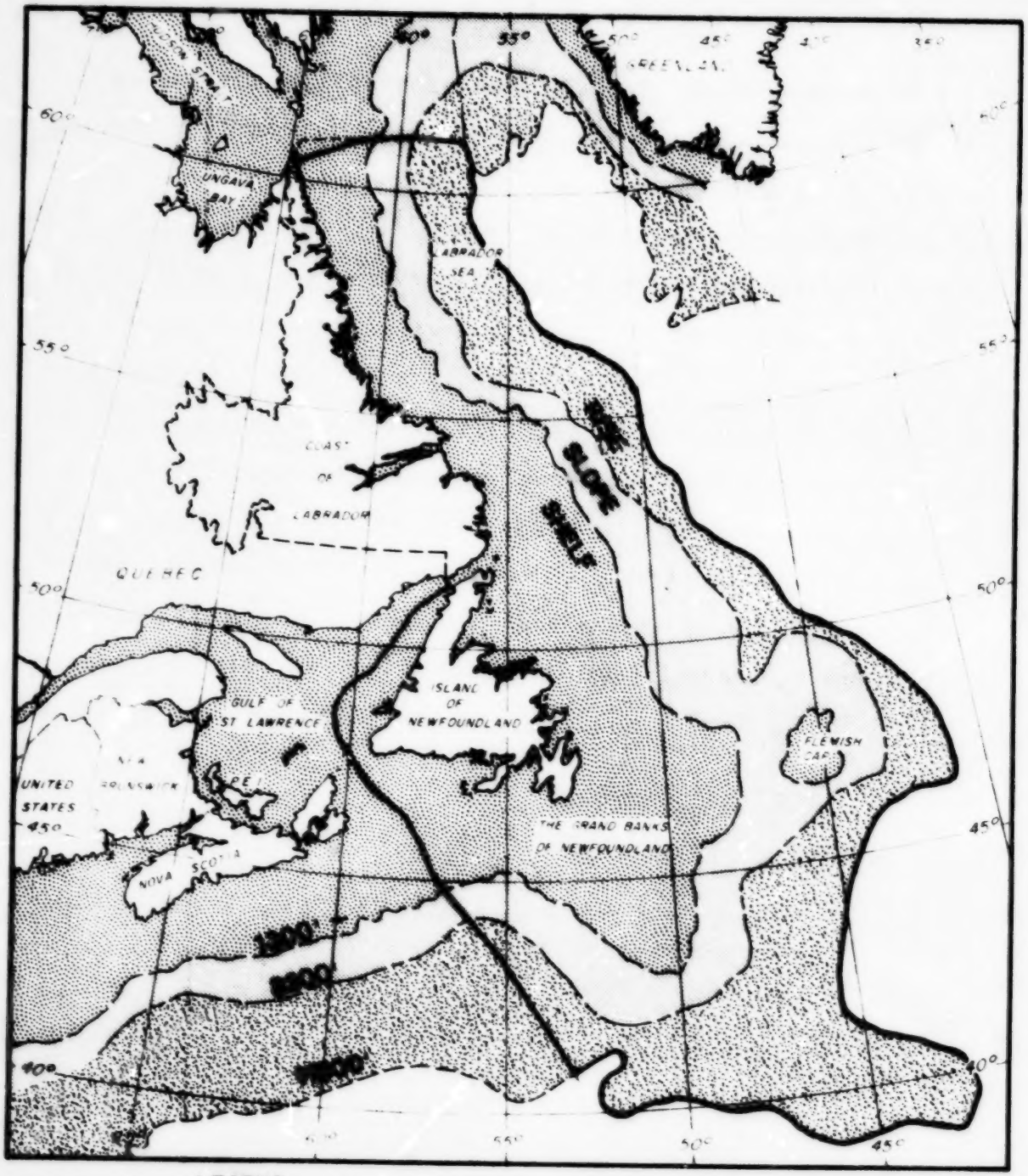
Table 5

Resource Potential for the Labrador Margin

Probability (Percent)	Recoverable Oil Resource BSTB	Recoverable Gas TSCF
90	0.3	10.6
50	1.8	44.1
10	8.6	167.0

DISCUSSION

The continental margin of Newfoundland and Labrador encompasses an area of some 714,000 square miles (Figure 7) and to the end of 1982 it has been lightly explored (i.e., 78 wildcat wells out of a total of 87 wells or one exploratory well per 9150 square miles). Seventy-six exploratory wells have been drilled on the shelf; 2 on the slope and none on the rise. On average, the 8200 foot isobath is the boundary between slope and rise and as a consequence the rise is beyond the range of current drilling technology. Technology exists to drill in water depths of at least 5000 feet, so roughly one-half the area of the slope and all of the shelf are currently within drilling range. The area encompassed by the 5000 foot isobath is approximately 373,000 square miles. This area has a drilling density of one exploratory well per 4780 square miles. From the standpoint of hydrocarbon potential, however, this area has to be further reduced to account for the non prospective rocks (mostly Pre-Cambrian) that subcrop at the sea floor, and to account for basement highs with thin sedimentary sections. That reduction, largely within the shelf area is in the order of 25%. As a result, the currently drillable prospective area within the continental margin is determined at approximately 280,000 square miles with a very low resultant drilling density of one well per 3600 square miles of area. Offshore Newfoundland and Labrador remains a lightly explored, 'frontier' area.



LEGEND

PHYSICAL CONTINENTAL SHELF

CONTINENTAL SLOPE

CONTINENTAL RISE

km 200 0 200 400 600 km

CONTINENTAL MARGIN
AREA : 714,000 sq. mi.

FIG. 7

We believe that in the order of 15 to 20 percent and 4 to 8 percent of the stated recoverable oil and gas resource at the 50% probability level, has already been discovered. Much of the discovered gas is located in the Labrador Margin sector and, excluding the 'waxy' oil discovery at the North Leif well (Figure 1), all of the discovered oil is in the Northern Grand Banks sector.

This report has fulfilled three of the four objectives in making estimates of resource potential as outlined at the beginning (i.e., volume, probability, and location) but the fourth (commerciality) will require additional evaluation. By necessity, such an evaluation, at the very least, would include predictive studies of price-cost relationships, and future drilling and production technology.

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